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BIOLOGICAL BULLETIN

OF THE

Marine Biological Laboratory

WOODS HOLE, MASS.

VOL. XLI JULY, 1921 NO. 1

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George T. Moore—*The Missouri Botanic Garden.*

T. H. Morgan—*Columbia University.*

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BIOLOGICAL BULLETIN

THE MARINE BIOLOGICAL LABORATORY

TWENTY-THIRD REPORT; FOR THE YEAR 1920.

TWENTY-THIRD YEAR.

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I. TRUSTEES

EX OFFICIO.

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GILMAN A. DREW, *Assistant Director*, Marine Biological Laboratory.
D. BLAKELY HOAR, *Treasurer*, 161 Devonshire Street, Boston, Mass.
GARY N. CALKINS, *Clerk of the Corporation*, Columbia University.

TO SERVE UNTIL 1924.

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CASWELL GRAVE, Washington University.
W. E. GARREY, Tulane University.
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TO SERVE UNTIL 1922.

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TO SERVE UNTIL 1921.

S. F. CLARKE, Williamstown, Mass.
CHARLES A. COOLIDGE, Ames Building, Boston, Mass.
C. R. CRANE, Woods Hole, Mass., *President of the Corporation*.
ALFRED G. MAYOR, Carnegie Institution.
C. E. MCCLUNG, University of Pennsylvania.
T. H. MORGAN, Columbia University.
ERWIN F. SMITH, United States Department of Agriculture.
E. B. WILSON, Columbia University.

II. ACT OF INCORPORATION

No. 3170.

COMMONWEALTH OF MASSACHUSETTS.

Be It Known, That whereas Alpheus Hyatt, William Sanford Stevens, William T. Sedgwick, Edward G. Gardiner, Susan Minns, Charles Sedgwick Minot, Samuel Wells, William G. Farlow, Anna D. Phillips and B. H. Van Vleck have associated themselves with the intention of forming a Corporation under the name of the Marine Biological Laboratory, for the purpose of establishing and maintaining a laboratory or station for scientific study and investigation, and a

school for instruction in biology and natural history, and have complied with the provisions of the statutes of this Commonwealth in such case made and provided, as appears from the certificate of the President, Treasurer, and Trustees of said Corporation, duly approved by the Commissioner of Corporations, and recorded in this office;

Now, therefore, I, HENRY B. PIERCE, Secretary of the Commonwealth of Massachusetts, *do hereby certify* that said A. Hyatt, W. S. Stevens, W. T. Sedgwick, E. G. Gardiner, S. Minns, C. S. Minot, S. Wells, W. G. Farlow, A. D. Phillips, and B. H. Van Vleck, their associates and successors, are legally organized and established as, and are hereby made, an existing Corporation, under the name of the MARINE BIOLOGICAL LABORATORY, with the powers, rights, and privileges, and subject to the limitations, duties, and restrictions, which by law appertain thereto.

Witness my official signature hereunto subscribed, and the seal of the Commonwealth of Massachusetts hereunto affixed, this twentieth day of March, in the year of our LORD ONE THOUSAND, EIGHT HUNDRED and EIGHTY-EIGHT.

HENRY B. PIERCE,
Secretary of the Commonwealth.

[SEAL.]

III. BY-LAWS OF THE CORPORATION OF THE MARINE BIOLOGICAL LABORATORY

I. The annual meeting of the members shall be held on the second Tuesday in August, at the Laboratory, in Woods Hole, Mass., at 12 o'clock noon, in each year, and at such meeting the members shall choose by ballot a Treasurer and a Clerk, who shall be, *ex officio*, members of the Board of Trustees, and Trustees as hereinafter provided. At the annual meeting to be held in 1897, not more than twenty-four Trustees shall be chosen, who shall be divided into four classes, to serve one, two, three, and four years, respectively, and thereafter not more than eight Trustees shall be chosen annually for the term of four years. These officers shall hold their respective offices until others are chosen and qualified in their stead. The Director and Assistant Director, who shall be chosen by the Trustees, shall also be Trustees, *ex officio*.

II. Special meetings of the members may be called by the Trustees, to be held in Boston or in Woods Hole at such time and place as may be designated.

III. The Clerk shall give notice of meetings of the members by

publication in some daily newspaper published in Boston at least fifteen days before such meeting, and in case of a special meeting the notice shall state the purpose for which it is called.

IV. Twenty-five members shall constitute a quorum at any meeting.

V. The Trustees shall have the control and management of the affairs of the Corporation; they shall present a report of its condition at every annual meeting; they shall elect one of their number President and may choose such other officers and agents as they may think best; they may fix the compensation and define the duties of all the officers and agents; and may remove them, or any of them, except those chosen by the members, at any time; they may fill vacancies occurring in any manner in their own number or in any of the offices. They shall from time to time elect members to the Corporation upon such terms and conditions as they may think best.

VI. Meetings of the Trustees shall be called by the President, or by any two Trustees, and the Secretary shall give notice thereof by written or printed notice sent to each Trustee by mail, postpaid. Seven Trustees shall constitute a quorum for the transaction of business. The Board of Trustees shall have power to choose an Executive Committee from their own number, and to delegate to such Committee such of their own powers as they may deem expedient.

VII. The President shall annually appoint two Trustees, who shall constitute a committee on finance, to examine from time to time the books and accounts of the Treasurer, and to audit his accounts at the close of the year. No investments of the funds of the Corporation shall be made by the Treasurer except approved by the finance committee in writing.

VIII. The consent of every Trustee shall be necessary to dissolution of the Marine Biological Laboratory. In case of dissolution, the property shall be given to the Boston Society of Natural History, or some similar public institution, on such terms as may then be agreed upon.

IX. These By-Laws may be altered at any meeting of the Trustees, provided that the notice of such meeting shall state that an alteration of the By-Laws will be acted upon.

X. Any member in good standing may vote at any meeting, either in person or by proxy duly executed.

IV. THE TREASURER'S REPORT

MARINE BIOLOGICAL LABORATORY BALANCE-SHEET, DECEMBER 31, 1920.

Assets.

Cash:		
In bank	$ 572.52	
Petty cash fund	200.00	$ 772.52
Notes receivable (secured)		1,000.00
Accounts receivable		11,706.37
Inventories:		
Supply department	$ 15,796.63	
BIOLOGICAL BULLETIN	3,995.02	19,791.65
Investments:		
Securities (Schedule I.)	$ 11,697.43	
Cash (Schedule II.)	712.23	12,409.66
Stock in General Biological Supply House, Inc.		12,500.00
Gansett property account	$ 19,739.27	
Less mortgage	12,132.01	7,607.26
Educational Plant (Schedule III.): Land	$ 95,856.14	
Buildings	191,301.09	
Equipment	89,110.40	
	$376,267.63	
Less reserve for depreciation	34,799.48	341,468.15
Deferred charges:		
Prepaid insurance		3,832.17
Items in suspense		35.85
		$411,123.63

Liabilities.

Accounts payable		$ 4,631.49
Notes payable:		
Falmouth National Bank	$ 5,000.00	
Issued in part payment of shares of General Biological Supply House, Inc. purchased	2,500.00	7,500.00
Accrued charges (estimated)		1,000.00
Trust funds	$ 10,409.66	
Note payable issued on account of purchase of reserve fund securities	2,000.00	12,409.66
		$ 25,541.15

Balancing account:			
Balance, January 1		$359,923.00	
Inventories and sundry capital expenditures set up during year		22,996.65	
Special donations		8,500.00	
Appropriation from Library Fund for purchase of books		813.91	
		$392,234.46	
Deduct, net loss on mess hall and equipment destroyed by fire March 17, 1920	$6,041.33		
Deduct, excess of expenses for year	610.65	6,651.98	385,582.48
			$411,123.63

MARINE BIOLOGICAL LABORATORY, INCOME-AND-EXPENSE FOR YEAR ENDED DECEMBER 31, 1920

	Expense	Income	Loss	Gain
Administration expenses	$ 9,114.98		$ 9,114.98	
Bar Neck property expenses	184.00		184.00	
BIOLOGICAL BULLETIN and annual dues	4,891.86	3,105.75	1,786.11	
BIOLOGICAL BULLETIN, additional expenses for 1919	886.72		886.72	
Carpenter department	909.38	22.90	886.48	
Chemical department	1,647.58		1,657.58	
Dormitories	2,219.51	2,234.18		14.67
Instruction	6,615.36	5,960.00	655.36	
Interest on notes payable	126.55		126.55	
Janitor's house expenses	3.31		3.31	
Lectures, evening	28.22		28.22	
Lectures, philosophical	100.00		100.00	
Library department	2,018.95		2,018.95	
Maintenance, buildings and grounds	6,057.05		6,057.05	
Mess	23,214.76	23,476.72		261.96
New laboratory expenses	2,820.61		2,820.61	
Newman Cottage	49.61		49.61	
Pumping station	228.66		228.66	
Research department	2,571.15	4,450.00		1,878.85
Sundry expense and income	946.27	7,030.75		6,084.48
Supply department	37,672.24	43,662.74		5,990.50
Truck	790.87		790.87	
Total current expenses	$103,097.64		$27,385.06	
Total current income	89,943.04	$89,943.04	14,230.46	$14,230.46

	Expense	Income	Loss	Gain
Excess of expenses	$13,154.60		$13,154.60	
Reserve for depreciation	7,270.69			
Bad accounts written off	245.36			
	$20,670.65			
Donations:				
Friendship Fund $20,000.00				
Other 60.00	20,060.00			
Balance to balancing account	$610.65			

MARINE BIOLOGICAL LABORATORY, SUMMARY OF INVENTORY OF LAND, BUILDINGS, AND EQUIPMENT, DECEMBER 31, 1920.

A. Land, January 1, 1920			$ 95,856.14
B. Buildings, January 1, 1920		$174,713.44	
Permanent improvements during year:			
New mess hall		14,400.46	
Supply department laboratory		9,205.08	
New laboratory (chemical room extra)		670.94	
Janitor's house		628.41	
New laboratory (third floor improvements)		203.14	
Supply department improvements		14.10	
Mess improvements		27.92	
		$199,863.49	
New refrigerator built in 1919		1,321.57	
		$201,185.06	
Deduct cost of mess hall destroyed by fire March 17, 1920		9,883.97	191,301.09
C. Equipment, January 1, 1920		$ 78,179.37	
Expenditures for new equipment during year:			
Mess hall		6,414.44	
Books and periodicals for library		2,686.16	
New truck		728.14	
Chemical department		267.30	
Carpenter shop		113.87	
Gas machine		108.80	
Supply department		103.50	
New laboratory		57.49	
Main building		11.08	
Dormitories		10.00	
Miscellaneous		56.14	
		$88,736.29	

Cost of books and periodicals purchased in 1916, 1917, 1918, and 1919 set up	3,951.15	
	$92,687.44	
Deduct cost of mess hall equipment destroyed by fire March 17, 1920	3,577.04	89,110.40
		$376,267.63

January 20, 1921.

MR. D. BLAKELY HOAR,
161 Devonshire Street,
Boston.

Dear Sir: We have completed our audit of the accounts of the Marine Biological Laboratory for the year ended December 31, 1920, as kept both at your office in Boston and at Woods Hole, and report thereon in the accompanying exhibits and schedules:

Exhibit A—Balance-Sheet as of December 31, 1920.
B—Income-and-Expense for the Year ended December 31, 1920.

Schedule I—Investments (Book Values).
II—Cash Receipts and Payments on Account of Investments.
III—Summary of Inventory of Land, Buildings, and Equipment.
IV—Depreciation Reserve.
V—Supply Department Income-and-Expense for the Year ended December 31, 1920.

We certify that, subject to the comments herewith, the balance-sheet and income-and-expense statement shown in Exhibits A and B are in accordance with the books and correct to the best of our knowledge and belief.

Very respectfully,
HARVEY S. CHASE & CO.,
Certified Public Accountants.

V. REPORT OF THE LIBRARIAN.

The Library has continued to make a satisfactory growth. The total accessions during the year, not counting periodicals received in parts, were 795 items, of which 175 were received by purchase, 93 by binding, and 514 by gift and exchange. After deducting 13 duplicate volumes removed from the collection, the net increase was 408 volumes and 387 pamphlets, making the total contents of the library on December 31, 1920, 10,243 volumes and 8,532 pamphlets.

The current periodicals and other serial publications, received during the year, comprised 153 titles, of these 83 were received by subscription, 38 in exchange for the BIOLOGICAL BULLETIN, and 32 were gifts. The list of periodicals was increased over the previous year by the addition of 21 titles.

The appropriation of part of the reserve Library Fund made it possible to fill up the gaps in the sets of German periodicals occasioned by the interruption of communication during the war, and also to complete the sets of a number of important journals. As the result of much labor and correspondence the following sets were completed: *Archiv für mikroscopische Anatomie* (except 2 vols.), *Archives de Biologie*, *Biochemical Journal*, *Botanical Abstracts*, *Journal of the New York Botanical Garden*, *Journal of the Royal Microscopical Society*, *New Phytologist* (except 1 vol.), *Parasitology*.

There are still many important sets of journals in the library that are incomplete. And one of the pressing needs of the Laboratory is funds with which to purchase the volumes necessary to complete them.

During the summer the library was in constant use by officers and students of the Laboratory and much of the time of the Assistant Librarian was taken up with assisting readers and attending to the circulation of books. About 1,000 books and periodicals were lent for use outside of the Library.

When the collection was small, the arrangement of the books and pamphlets was a simple matter, and there was little need of a catalogue, except as a matter of record. The collection has

now reached so considerable a size that it has become necessary to adopt a definite system of classification and to revise the catalogue so as to make it a useful instrument for finding a book or in searching the literature on a given subject. After careful consideration of the various schemes of classification in general use, it was decided to use, with some modifications, the Dewey Decimal Classification. The main reason for adopting this system was that it seems to be the one most familiar to biologists. During the spring the bound volumes were rearranged and roughly classified according to this system, and during the autumn this work has been continued. The classification is nearly completed, and the corresponding numbers have been placed on the books and on the cards in the catalogue. It is hoped that this work will greatly facilitate the use of the library during the coming summer.

The old arrangement of the pamphlets, alphabetically by authors, has been retained, and in order to aid in finding them, numbers have been assigned to them and have been placed on the catalogue cards; the Cutler notation being used for this purpose.

For the bound volumes a new catalogue has been started on the dictionary principle, author, title and subject entries being arranged in one alphabet.

Much work has still to be done, but it is hoped that the books and the catalogue may ultimately be arranged so as to make the resources of the Library as quickly and easily available as possible.

Another important aim for the future is to complete the sets of important periodicals, and to gather together a complete set of the reprints of investigators, so that the library will fully represent the work done directly or indirectly in the Laboratory. And finally it is hoped that it may be possible to develop the Library symmetrically, so that each branch of Biology may be equally well represented on its shelves.

In conclusion, grateful acknowledgment should be made of the many generous gifts to the Library. Gifts of money have been received from Dr. M. M. Metcalf, $50.00 toward the purchase of volumes of periodicals to complete sets; and from Dr. A. G. Mayor, $10.00 for subscriptions to current journals.

Books have been received from Dr. Marianna L. Herwerden, Dr. E. G. Spaulding, Dr. Dunn, Dr. A. R. Moore, Rev. Mr. Tingley, Mrs. Charles R. Crane, Dr. F. R. Lillie, Dr. Christine Ladd-Franklin, Dr. Otto C. Glaser, the New York Botanical Garden, and others.

ROBERT P. BIGELOW,
Librarian.

VI. THE DIRECTOR'S REPORT.

January 1, 1921.

TO THE TRUSTEES OF THE MARINE BIOLOGICAL LABORATORY.

Gentlemen: I beg to present herewith a report of the thirty-third session of the Laboratory for the year 1920:

On March 17, 1920, the dining hall, kitchen and laundry of the Laboratory were entirely destroyed by a fire which started in the machine shop of the Bureau of Fisheries across the street, and was blown by a strong west wind directly on to our buildings. Although the fire started at 4.30 A.M. the entire town turned out, and by hard work succeeded in saving the other buildings of the Laboratory. A meeting of the members of the Board of Trustees resident in New York and vicinity was hurriedly called on March 20th at the home of Mr. Crane, and voted that "the officers of the Laboratory be empowered to make necessary arrangements to replace the buildings and equipment destroyed by fire, enlarging the same if deemed advisable; and that the Director and Treasurer be given power to borrow the funds necessary for these purposes." A waiver of notice of time and place of this meeting was then sent out and was signed by all members of the Board.

Dr. Drew took charge of the building operations, and, in spite of the unprecedently bad conditions of the market both for labor and materials, he succeeded with the loyal assistance of the Laboratory crew in getting the buildings and equipment ready for opening at the regular time. As the amount of insurance had remained at pre-war rates, a very heavy net loss resulted, which is recorded in the Treasurer's report.

This accident resulted in the interruption of construction of the laboratory of the Supply Department, referred to in my previous report, which was under way at the time, and in diversion of the funds set apart for this purpose. In this emergency Mr. Crane again came to our assistance and furnished the funds needed for the completion of the Supply Department laboratory, the building of which was resumed in the late summer, and is now in process of completion.

The number of colleges, universities and other institutions that coöperate with the Laboratory by subscribing for research rooms and for investigators' or students' tables continues to grow. In 1915 there were 37; 1916, 40; 1917, 38: 1918, 33; 1919, 48; 1920, 52. (See appended list.)

The attendance at the Laboratory was again so large as to tax the capacity of the buildings to the uttermost. The tabular view of attendance (p. 26) shows a total attendance of 256 of whom 120 were students in courses. It was felt that the student laboratories had been unduly crowded last year, especially in embryology and physiology, and a number of student applications were therefore refused, and this explains the slightly smaller student attendance in 1920 compared with 1919. The number of investigators was 136 in 1920, 134 in 1919.

It was felt to be necessary to increase research space for another year, and it was therefore decided to complete the unfinished half of the third floor of the brick building hitherto used for storage. Aid for this work came from the Eli Lilly Co., of Indianapolis, through Dr. G. H. A. Clowes of their research laboratory, who had been carrying on biochemical investigations at the Laboratory for several years. Later the Nela Research Laboratory of the National Lamp Works of the General Electric Co. entered into a similar arrangement through Dr. R. S. Lillie, who was appointed biologist in their organization. By the terms of agreements entered into with these companies they will contribute funds to complete for their own use definitely assigned sections of the new research space, and pay the usual annual fees for their workers at the Laboratory, which on its part agrees to furnish the usual assistance rendered to research workers at the

Laboratory; these agreements run for a period of ten years. The Eli Lilly Co. rooms will be specially equipped for biochemistry, and the Nela Research Laboratory rooms for biophysics, especially radiation work. Thus experience of the special needs in these subjects will be gained in advance of the contemplated erection of a special laboratory for biochemistry and biophysics. The greater part of the new space is involved in these assignments, but other space is also thereby released, making a net gain to the Laboratory of five research rooms.

Additional research rooms can also be secured by the temporary occupation of a portion of the new Supply Department Laboratory, so that accommodations will be more ample for 1921. The relief must, however, be very temporary, and accordingly comprehensive plans for the future development of the Laboratory were studied by members of the Board of Trustees during the summer.

It was decided that any new construction should be part of a plan calculated to meet the needs of the present generation of biologists, and accordingly Mr. Charles A. Coolidge was requested, and kindly consented, to prepare such plans. The obvious immediate needs call for two new buildings, a laboratory building specially equipped for biochemistry and biophysics, and a building for library and administration purposes containing also an auditorium. Future development will require an additional laboratory unit, and this also was included in the plans.

The first two of these buildings should be constructed immediately. As regards the first: not only is present research space inadequate, but, as noted in the last report, the present wooden buildings are not well adapted to the more rigorous needs of modern experimental research. The new laboratory would be fully occupied at once by workers transferred from the old buildings who require the special facilities proposed, and this would leave more space in the old buildings for those whose work has other technical requirements. This building is the one approved by the National Research Council as one of their projects, as related in the report for 1919.

A committee was appointed by the Trustees to consider the

internal plans of this building in consultation with Mr. Coolidge. The members of this committee are C. E. McClung (chairman), G. H. A. Clowes, R. S. Lillie, A. P. Mathews and W. J. V. Osterhout. Plans have been drawn up after much study, making the building a wing of the present brick research laboratory extending to the west. It will include about 36 research laboratories and rooms, five dark rooms and laboratories, refrigeration and constant temperature rooms, and space for storage. Some of the research laboratories and rooms will have a strictly biological equipment, others a biochemical equipment, others again biophysical equipment; and it is proposed to interrelate the various types for the most effective coöperation. It is expected that the facilities will be adequate for the most exacting kinds of physical and chemical work adapted to biological analysis.

The second building will extend to the north of the proposed new laboratory and will be connected with it by a corridor. It will be primarily a library building, calculated to be sufficient for the library development of many years to come, and capable of expansion if needed. Administration offices, committee rooms and a demonstration hall will occupy the first floor; and an auditorium will be built out to the east (rear) with access from the demonstration hall. The facilities of this building are greatly needed at the present time. The present administration offices are too small, inconvenient for those who use them, and a source of distraction in the research building in which they are located. The present library rooms are already well filled, and do not provide space for much growth. The present lecture hall is so inadequate that the evening lectures are usually uncomfortably crowded, and attendance at them is discouraged. The committee in charge of this building is G. A. Drew (chairman), R. P. Bigelow, M. J. Greenman, George Lefevre and G. H. Parker.

The third proposed unit will be a laboratory building forming a wing of the present brick laboratory, extending to the east and balancing the proposed west wing. It is not anticipated that it will be needed for a few years yet.

The funds for these buildings and for their maintenance remain to be secured. The chairman of the Division of Biology and

Agriculture of the National Research Council is giving the project for the laboratory of biochemistry and biophysics unremitting personal attention, and other officers of the Council are interesting themselves in the matter as one of their chief projects. Building costs are, however, at their maximum just now, and it is doubtful that any who might be disposed to contribute to these buildings would consider it wise to undertake construction until there has been a considerable reduction of prices. In the meantime, if representatives of all of the 50 or more coöperating universities, colleges and research organizations, and of the industrial research laboratories interested would unite their efforts, the way should be open soon for the construction of the first of these units. The Library, Administration and Lecture Hall building should appeal to a still wider circle, including those interested in the development of Woods Hole as a summer home.

It is perhaps not generally recognized to what an extent costs of operation have increased during the last few years: in 1918 the total current expenditures of the Laboratory amounted to $69,687.14, in 1919 to $88,452.64 and in 1920 to $103,097.64. The current *earned* income for the same years was $54,282.05 (1918), $80,307.57 (1919) and $89,943.04 (1920). This period was one of rapidly mounting costs in supplies of all kinds and in labor;[1] it is not to be expected that 1921 will show an appreciable increase over 1920; indeed, it is to be hoped that some saving can be effected through the fall in prices. It is a matter for congratulation that the various earning departments of the Laboratory were able to keep up with rising prices so that the excess of expenses over income, which is covered by donations, was $7,300.02 less in 1919, and $2,251.49 less in 1920, than in 1918. The Supply Department is largely responsible for this good showing, having increased its income from $22,608.04[2] in 1918 to $43,662.74 in 1920, while its expenses increased during the same period from $25,611.73[2] in 1918 to $37,672.24 in 1920.

[1] The costs of salaries and wages in 1918, 1919 and 1920 were $33,630.06, $40,307.28 and $54,097.67 respectively.

[2] The system of accounting for the Supply Department was changed in 1919, and the figures given for 1918 are arrived at by applying the 1919 system to the figures given in the treasurer's report for 1918.

Thus an actual loss in 1918 was converted into a reasonable profit both in 1919 and 1920. But all departments show increase of expense, and all earning departments increase of income.

The financial difficulties of 1920 came not from the cost of ordinary operations, but from the losses incident to the fire, and the increased insurance which it was felt necessary to place on the buildings and equipment, and from other capital expenditures. The cost of replacing the mess hall and equipment amounted to $20,814.90 in 1920. The insurance received on the old mess hall and contents was $6,318.54. The net expenditure on this item was therefore $14,496.36. The cost of new insurance was $4,194.72, and, although this covers three to five years insurance, the payments had to be made during the year. Expenditures on the new Supply Department Laboratory exceeded Mr. Crane's special gift by $705.08 during the year. $2,500.00 was invested in new stock of the General Biological Supply House. These expenditures, amounting to $21,896.16, will explain how a cash balance of $14,277.69 on December 31, 1919, was reduced to $772.52 on December 31, 1920, and why it was necessary to borrow $5,000.00 from the Falmouth National Bank. With the cessation of such capital expenditures the current income is adequate to carry all ordinary current expenditures.

Since 1896 the charge for tuition in each of the courses has been $50.00. In 1920 the cost of instruction was $6,615.36 and the income $5,960.00. The salaries paid the instructors, though somewhat increased in the last two years, have been kept consistently low. There are no charges for use of the boats or for equipment, rent, or depreciation. Applications for admission to courses have exceeded accommodations in the last two years. As our Laboratory is primarily a research institution, it is believed that instruction should be self-supporting and of a rigorously professional type. It was therefore decided to raise the fee for each course of instruction to $75.00 beginning 1921. It is hoped that the increase will not debar any who are professionally interested; a hindrance that will exclude any not so interested will not be harmful to the research activities of the Laboratory.

There are appended as parts of this report, lists of the staff and of investigators and students for 1920, a tabular view of attendance from 1916–1920; also lists of the coöperating and subscribing institutions, of the evening lectures and of membership of the Corporation.

1920.

THE STAFF

FRANK R. LILLIE, *Director*, Professor of Embryology, and Chairman of the Department of Zoölogy, The University of Chicago.

GILMAN A. DREW, *Assistant Director*, Marine Biological Laboratory.

ZOÖLOGY.

I. INVESTIGATION.

GARY N. CALKINS, Professor of Protozoölogy, Columbia University.

E. G. CONKLIN, Professor of Zoölogy, Princeton University.

GILMAN A. DREW, Assistant Director, Marine Biological Laboratory.

GEORGE LEFEVRE, Professor of Zoölogy, The University of Missouri.

FRANK R. LILLIE, Professor of Embryology, The University of Chicago.

C. E. MCCLUNG, Professor of Zoölogy, University of Pennsylvania.

T. H. MORGAN, Professor of Experimental Zoölogy, Columbia University.

E. B. WILSON, Professor of Zoölogy, Columbia University.

II. INSTRUCTION.

W. C. ALLEE, Professor of Biology, Lake Forest College.

ROBERT HALL BOWEN, Instructor in Zoölogy, Columbia University.

J. A. DAWSON, Dalhousie University.

R. T. HANCE, Instructor in Zoölogy, University of Pennsylvania.

C. L. PARMENTER, Instructor in Zoölogy, University of Pennsylvania.

CHRISTIANNA SMITH, Instructor in Zoölogy, Mount Holyoke College.

J. P. VISSCHER, Graduate Student, Johns Hopkins University.

DONNELL B. YOUNG, Instructor in Biology, Dalhousie University.

PROTOZOÖLOGY.

I. INVESTIGATION.

(*See Zoölogy.*)

II. INSTRUCTION.

GARY N. CALKINS, Professor of Protozoölogy, Columbia University.
LOUISE H. GREGORY, Assistant Professor of Zoölogy, Barnard College.

EMBRYOLOGY.

I. INVESTIGATION.

(See Zoölogy.)

II. INSTRUCTION.

DAVID H. TENNENT, Professor of Biology, Bryn Mawr College.
CHARLES G. ROGERS, Professor of Comparative Physiology, Oberlin College.
HUBERT B. GOODRICH, Associate Professor of Zoölogy, Wesleyan University.
BENJAMIN H. GRAVE, Professor of Biology, Wabash College.
ELIZABETH A. SMITH, Assistant Professor of Zoölogy, University of Wisconsin.

PHYSIOLOGY.

I. INVESTIGATION.

ALBERT P. MATHEWS, Professor of Biochemistry, The University of Cincinnati.
RALPH S. LILLIE, Professor of Biology, Clark University.
HAROLD C. BRADLEY, Assistant Professor of Physiological Chemistry, University of Wisconsin.

II. INSTRUCTION.

RALPH S. LILLIE, Professor of Biology, Clark University.
WALTER E. GARREY, Professor of Physiology, Tulane University.
FRANK P. KNOWLTON, Professor of Physiology, Syracuse University.
R. A. SPAETH, School of Public Health, Johns Hopkins University.

PHILOSOPHICAL ASPECTS OF BIOLOGY AND ALLIED SCIENCES.

LECTURER.

EDWARD G. SPAULDING, Professor of Philosophy, Princeton University.

BOTANY.

I. INVESTIGATION.

S. C. BROOKS, Associate Professor of Physiology and Biochemistry, Bryn Mawr College.
EDWARD M. EAST, Professor of Experimental Plant Morphology, Harvard University.

ROBERT A. HARPER, Professor of Botany, Columbia University.
E. NEWTON HARVEY, Assistant Professor of Physiology, Princeton University.
WINTHROP J. V. OSTERHOUT, Professor of Botany, Harvard University.

II. INSTRUCTION.

IVEY F. LEWIS, Professor of Biology, University of Virginia.
WILLIAM RANDOLPH TAYLOR, Instructor in Botany, University of Pennsylvania.
CONRAD ZIRKLE, Instructor in Botany, University of Virginia.

LIBRARY.

ROBERT P. BIGELOW, Librarian and Associate Professor of Zoölogy and Parasitology, Massachusetts Institute of Technology. Librarian,
PRISCILLA B. MONTGOMERY (Mrs. Thomas H. Montgomery, Jr.). Assistant Librarian.

CHEMICAL SUPPLIES.*

OLIVER S. STRONG, Associate Professor of Neurology, Columbia University, New York City, Chemist.

SUPPLY DEPARTMENT.

G. M. GRAY, Curator.
JOHN J. VEEDER, Captain.
E. M. LEWIS, Engineer.
A. W. LEATHERS, Head of Shipping Department.
A. M. HILTON, Collector.
J. MCINNIS, Collector.
F. G. GUSTAFSON, Collector in Botany.
RUTH WINKLEY, Clerk.

F. M. MACNAUGHT, Business Manager.
HERBERT A. HILTON, Superintendent of Buildings and Grounds.

* Compound microscopes, with two oculars and two objectives, rack and pinion and fine adjustment, may be rented for the season at $7.00 each, provided notice is received by the Business Manager not later than June 15. Microscopes are not otherwise supplied by the Laboratory. See under Department of Chemical Supplies (p. 29).

2. STUDENTS AND INVESTIGATORS—1920

INDEPENDENT INVESTIGATORS—Zoölogy.

ADDISON, WILLIAM H. F., Professor of Normal Histology and Embryology, University of Pennsylvania.

ALLEE, WARDER C., Professor of Biology, Lake Forest College.

ALTENBURG, EDGAR, Instructor in Biology, Rice Institute.

AMBERSON, WILLIAM R., Graduate Fellow in Biology, Princeton University.

ANDERSON, ERNEST G., Carnegie Institution, Cold Spring Harbor.

BIGELOW, ROBERT P., Associate Professor of Zoölogy and Parasitology, Massachusetts Institute of Technology.

BISHOP, GEORGE H., Instructor in Zoölogy, Northwestern University.

BREITENBECKER, JOSEPH K., Assistant Professor of Biology, Western Reserve University.

BUDINGTON, ROBERT A., Professor of Zoölogy, Oberlin College.

CALKINS, GARY N., Professor of Protozoölogy, Columbia University.

CAROTHERS, E. ELEANOR, University of Pennsylvania.

CARPENTER, FREDERIC W., Professor of Biology, Trinity College.

CARROLL, MITCHEL, Professor of Biology, Franklin and Marshall College.

CHAMBERS, ROBERT, Assistant Professor of Anatomy, Cornell University Medical College.

CHARLTON, HARRY H., University of Missouri.

CLAPP, CORNELIA M., Professor Emeritus of Zoölogy, Mount Holyoke College.

CLARK, ELIOT R., Professor of Anatomy, University of Missouri.

CLARK, ELEANOR L., Columbia, Mo.

COPELAND, MANTON, Professor of Biology, Bowdoin College.

DANCHAKOFF, VERA, Assistant Professor of Anatomy, College of Physicians and Surgeons.

DAWSON, JAMES A., Professor of Biology, Dalhousie University.

DEDERER, PAULINE H., Associate Professor of Zoölogy, Connecticut College.

DODDS, GIDEON S., Assistant Professor of Histology, West Virginia University.

DREW, GILMAN A., Assistant Director, Marine Biological Laboratory, Woods Hole, Mass.

GLASER, OTTO C., Professor of Biology, Amherst College.

GOODRICH, HUBERT B., Associate Professor of Zoölogy, Wesleyan University.

GRAVE, BENJAMIN H., Professor of Biology, Knox College.

GRAVE, CASWELL, Professor of Zoölogy, Washington University.

GREGORY, LOUISE H., Assistant Professor of Zoölogy, Barnard College.

HANCE, ROBERT T., Instructor in Zoölogy, University of Pennsylvania.

HARVEY, ETHEL BROWNE, Princeton, N. J.

HEILBRUNN, LEWIS V., Instructor, University of Michigan.

JACOBS, MERKEL H., Assistant Professor of Zoölogy, University of Pennsylvania.

JENNINGS, HERBERT S., Professor of Zoölogy, Johns Hopkins University.

JUST, ERNEST E., Professor of Zoölogy, Howard University.

KINDRED, JAMES E., Assistant Professor of Biology, Western Reserve University.

KNOWER, HENRY MCE., Professor of Anatomy, University of Cincinnati.

LANGE, MATHILDE M., U. S. Dept. of Agriculture, New York City.
LEFEVRE, GEORGE, Professor of Zoölogy, University of Missouri.
LEWIS, WARREN H., Research Associate, Carnegie Institution of Washington.
LEWIS, MARGARET R., Collaborator, Carnegie Institution of Washington.
LILLIE, FRANK R., Chairman, Department of Zoölogy, University of Chicago.
MALONE, EDWARD F., Professor of Histology, University of Cincinnati.
MAST, SAMUEL O., Professor of Zoölogy, Johns Hopkins University.
MCCLUNG, CLARENCE E., Director of Zoölogical Laboratory, University of Pennsylvania.
METZ, CHARLES W., Research Associate, Carnegie Institution, Cold Spring Harbor.
MORRILL, CHARLES V., Assistant Professor of Anatomy, Cornell University Medical College.
MULLER, HERMANN J., Instructor, Columbia University.
NEAL, HERBERT V., Professor of Zoölogy, Tufts College, Mass.
OBRESHKOVE, VASIL, Instructor, Syracuse University.
PARKER, GEORGE H., Professor of Zoölogy, Harvard University.
PARMENTER, CHARLES L., Instructor, University of Pennsylvania.
PATTEN, WILLIAM, Professor of Biology, Dartmouth College.
POWERS, EDWIN B., Instructor in Zoölogy, University of Nebraska.
ROGERS, CHARLES G., Professor of Comparative Physiology, Oberlin College.
ROOT, FRANCIS M., Associate in Med. Entomology, School of Hygiene and Public Health, Johns Hopkins University.
SAGUCHI, SAKAE, Professor of Anatomy, Medical School, Kanazawa, Japan.
SMITH, ELIZABETH A., Assistant Professor of Zoölogy, University of Wisconsin.
SPEIDEL, CARL C., Adjunct Professor of Anatomy, University of Virginia.
STOCKARD, CHARLES R., Professor of Anatomy, Cornell University Medical College.
STRONG, OLIVER S., Associate Professor of Neurology, Columbia University.
TAYLOR, CHARLES V., University of California.
TENNENT, DAVID H., Professor of Biology, Bryn Mawr College.
TRACY, HENRY C., Professor of Anatomy, University of Kansas.
WHITE, GERTRUDE W., Instructor, Carnegie Institute of Technology.
WIEMAN, HARRY L., Professor of Zoölogy, University of Cincinnati.
WOOD, F. E., Professor of Biology, Illinois Wesleyan University.
WOODWARD, ALVALYN E., Amherst College.
ZELENY, CHARLES, Professor of Zoölogy, University of Illinois.

BEGINNING INVESTIGATORS—Zoölogy.

AGERSBORG, H. P. K., Assistant in Zoölogy, Columbia University.
BOWEN, ROBERT H., Instructor in Zoölogy, Columbia University.
COHEN, BARNETT, Student, Yale University.
DEMCREC, MILISLAV, Assistant, Carnegie Institution of Washington.
DRIVER, CHARLES S., Columbia University.
GUTHRIE, MARY J., Demonstrator, Bryn Mawr College.
HARRAH, EZRA C., University of Illinois.
HIBBARD, HOPE, Fellow in Biology, Bryn Mawr College.
HINRICHS, MARIE A., Laboratory Assistant, University of Chicago.
HUETTNER, ALFRED F., Assistant in Zoölogy, Columbia University.
JOHNSON, HENRY H., JR., Assistant, Columbia University.

KING, ROBERT L., University of Pennsylvania.
KIRK, WINIFRED, Technician in Histology, Cornell University Medical College.
LANCEFIELD, DONALD E., Assistant, Columbia University.
LANCEFIELD, REBECCA C., Assistant, Carnegie Institution.
MASON, ELEANOR D., Assistant, Carnegie Institution.
MOSES, MILDRED S., Assistant, Carnegie Institution.
NUTE, BERTHA E., Teacher of Science, Hastings-on-Hudson, N. Y.
PAGE, IRVINE A., Chemist, Eli Lilly & Co., Indianapolis, Ind.
RICHTER, MAURICE N., Student, College of Physicians and Surgeons.
ROMER, ALFRED S., Columbia University.
SEIDLIN, SAMUEL M., Student, College of Physicians and Surgeons.
SMITH, CHRISTIANNA, Instructor, Mount Holyoke College.
SWETT, FRANCIS H., Assistant, Yale University.
VISSCHER, J. PAUL, Instructor, Johns Hopkins University.
WARREN, HERBERT S., Graduate Student, Columbia University.
WILLIAMS, DOROTHY E., Laboratory Assistant, Mount Holyoke College.
YOUNG, DONNELL B., Acting Professor of Biology, Dalhousie University.
YOUNG, HELEN D., Research Assistant, Columbia University.

INDEPENDENT INVESTIGATORS—Physiology.

BRADLEY, HAROLD C., Professor of Physiological Chemistry, University of Wisconsin.
BROOKS, SUMNER C., Biologist, Dept. of Public Health, Washington, D. C.
BROOKS, MATILDA M., 3809 Yuma St., Washington, D. C.
CLOWES, G. H. A., Director and Consulting Chemist, Research Laboratory, Eli Lilly & Co.
EDWARDS, DAYTON J., Instructor in Physiology, Cornell University Medical College.
FENN, WALLACE O., Instructor in Applied Physiology, Harvard Medical School.
GARREY, WALTER E., Professor of Physiology, Tulane University.
HARVEY, E. NEWTON, Professor of Physiology, Princeton University.
HECHT, SELIG, Assistant Professor of Physiology, Creighton University.
HOOKER, DONALD R., Associate Professor, Johns Hopkins University.
IRWIN, MARIAN, 46 Shepard St., Cambridge, Mass.
KNOWLTON, FRANK P., Professor of Physiology, Syracuse University.
LILLIE, RALPH S., Professor of Biology, Clark University.
LOEB, JACQUES, Head of Division of Experimental Biology, Rockefeller Institute.
LOEB, LEO, Professor of Comparative Pathology, Washington University.
MATHEWS, ALBERT P., Professor of Biochemistry, University of Cincinnati.
MORGULIS, SERGIUS, Professor of Biochemistry and Physiology, Creighton University College of Medicine.
PORTER, EUGENE L., Assistant Professor of Physiology, Western Reserve University.
SPAETH, REYNOLD A., Associate in Physiology, School of Public Health, Johns Hopkins University.
SPAULDING, E. G., Professor of Philosophy, Princeton University.
STEHLE, RAYMOND L., Assistant Professor of Physiological Chemistry, Medical School, University of Pennsylvania.
VON HERWERDEN, MARIANNE, University of Utrecht, Utrecht, Holland.

BEGINNING INVESTIGATORS—Physiology.

BACHMAN, EDA, Research Chemist, Eli Lilly & Co.
BASKERVILL, MARGARET L., Graduate Student, Columbia University.
FREIBERG, JOSEPH A., Medical College, University of Cincinnati.
KEITH, LUCILE G., Research Chemist, Eli Lilly & Co.
POND, SAMUEL E., Fellow, Clark University.
SAMPSON, MYRA M., Assistant Professor, Smith College.
YOSHIDA, SADAO, Professor, Osaka Medical College, Japan.

INDEPENDENT INVESTIGATORS—Botany.

HAZEN, TRACY E., Assistant Professor of Botany, Columbia University.
LEWIS, IVEY F., Professor of Biology, University of Virginia.
OSTERHOUT, WINTHROP J. V., Professor of Botany, Harvard University.
PHILLIPS, EVERETT F., Agriculturist, U. S. Dept. of Agriculture, Washington.
SCHRAMM, JACOB R., Professor of Botany, Cornell University.
TAYLOR, WILLIAM R., Instructor, University of Pennsylvania.
ZIRKLE, CONWAY, University of Virginia.

BEGINNING INVESTIGATORS—Botany.

GLUCK, MARGUERITE L., 2010 7th Ave., New York City.
INMAN, ONDESS L., Harvard University.

1920.

STUDENTS

ZOÖLOGY.

BALL, RUTH J., Assistant in Zoölogy Department, University of Vermont.
BELZER, KATHARINE, Student, Butler College.
BERRY, GEORGE P., Princeton University.
BISSONNETTE, THOMAS H., University of Chicago.
BLAIR, MONTGOMERY, JR., Student, Princeton University.
BUHRER, EDNA M., Student, Goucher College.
BUCKNELL, LYDIA E., Student, Oberlin College.
CASS, MILDRED F., Student, Doane College.
CATTELL, QUINTA, Garrison, N. Y.
CATTELL, WARE, Student, Columbia University.
CONKLIN, ISABEL, Student, Smith College.
CONOVER, L. LENORE, Detroit Normal College, Detroit, Mich.
COVENTRY, FRANCES A., Goucher College.
CROZIER, ANNIE J., Hunter College.
DRAKE, DOROTHY, Student, Simmons College.
EASTON, CHARLOTTE, Skidmore School of Arts.
EDSON, EDITH M., 511 Dewey Ave., Rochester, N. Y.
EIMERT, HELEN K., Student, Oberlin College.
ELIOT, ELLEN P., Student, Simmons College.
FLANAGAN, MARY C., Student, Simmons College.

FRUIT, IRMA B., Student, Knox College.
GRAVES, ISABELLE A., Student, Simmons College.
GREEN, WILMOTH, Teaching Fellow, Washington University.
GREGORY, ELIZABETH, Sophie Newcomb College.
GRIFFIN, MARY A., 615 McDonough St., Brooklyn, N. Y.
HERSHBERGER, RALPH E., Student, Heidelberg University.
HICKMAN, CLEVELAND P., Assistant in Zoölogy, University of Michigan.
HICKMAN, JENNINGS R., Assistant in Zoölogy, University of Michigan.
HOLE, FRANCES L., Student, Doane College.
HOOK, FLORA E., Head of Biology Department, East Orange High School.
HURD, ARCHER L., Student, Wesleyan University.
JOHNSON, MARIE M., Knox College.
KAAN, HELEN N., Assistant in Biology, Wheaton College.
KEELER, MARGERY, 28 Strawberry Hill, Stamford, Conn.
KIDNEY, MARY L., Teacher, Junior High, Quincy, Ill.
LARSON, JEAN C., Student, Oberlin College.
LEWIS, CLARA D., Student, Sophie Newcomb College.
LYMAN, ANNIE K., Student, Mount Holyoke College.
MATTER, KATHERINE E., Student, Oberlin College.
MCCOLLUM, RUTH, Student, Oberlin College.
MCDOWELL, CLAIRE, Laboratory Assistant, Mount Holyoke College.
MILLER, MINNIOLA O., Student, Connecticut College.
MILLIKIN, NEIL, Student, Johns Hopkins University.
MOSSMAN, ALEXANDER H., Amherst College.
OSGOOD, GEORGE W., Student, Tufts College.
QUINNAN, BERTHA C., Teacher, Pauline Shaw School, Boston.
POTTER, GRACE M., Student, Mount Holyoke College.
ROOT, SERAPH D., Student, Russell Sage College.
SEARCY, AUGUSTA T., Instructor in Biology, University of Alabama.
SHAHN, BENJAMIN H., Student, New York University.
SHEEHAN, FRED M., Student, Lake Forest College.
STOLL, HAROLD F., Student, Western State Normal School.
THORP, ERICA, 115 Brattle St., Cambridge, Mass.
WILLIAMS, S. CULVER, Student, Wesleyan University.
YOLTON, LEROY W., Student, Illinois Wesleyan University.
ZOOMAYA, EZRA B., Student, Lake Forest College.

PROTOZOÖLOGY.

DIETRICH, BERTHA K., Teacher, Bushwick High School, Brooklyn.
ELLIOTT, MARGARET E., Teaching Assistant, Wellesley College.
FARRAR, HILDA, Teacher of Biology, East High School, Rochester, N. Y.
GREENLEAF, WILLIAM E., Graduate Student, Yale University.
HELBIG, DOROTHY M., Hunter College.
LACKEY, JAMES B., Mississippi College.
LEIVA, LAMBERTO, Instructor in Parasitology, University of the Philippines.
LOWTHER, MRS. FLORENCE DEL., Instructor, Barnard College.
PROVOST, MARGARET, Teacher of Biology, Wadleigh High School, New York City.
SHEPPARD, ALICE E., 722 King St., Pottstown, Pa.

SPENCER, CLEMENTINA S., Assistant Professor, Coe College.
TUBANGUI, MARCOS A., Fellow, University of the Philippines.
UHLEMEYER, BERTHA, Assistant, Washington University.
WALLACE, GRACE N., Mount Holyoke College.
YOCUM, HARRY B., Assistant Professor, College of the City of New York.

EMBRYOLOGY.

BEAN, RAYMOND J., Instructor, Western Reserve University.
BURNS, ROBERT K., Bridgewater College.
COLDWELL, ESTHER I., Graduate Student, Johns Hopkins University.
DURYEA, ARTHUR W., Student, Dartmouth College.
FRIES, ERIK F. B., Student, Harvard University.
GRAHAM, MARGARET A., Instructor, Hunter College.
HALL-QUEST, SHIRLEY K., Clifton, Cincinnati, Ohio.
HANNUM, MARGARET H., Student, Smith College.
HERMETET, MCGREER, Student, Knox College.
HIPPOLITUS, JENNIE D., Student, Connecticut College.
JOHNSON, HELEN G., Teacher, Hartford High School.
JOHNSON, HENRY H., JR., Assistant in Zoölogy, Columbia University.
MA, P. W., North China Union College.
MCCLUNG, RUTH C., Student, Kansas University.
MONTANUS, JOHN J., Student, Long Island College Hospital.
PAXSON, ELEANOR M., Student, Swarthmore College.
PEARSE, HERMAN E., JR., Student, University of Missouri.
RAND, ELIZABETH P., Student, Wellesley College.
ROBBINS, HARRIET L., Teacher of Biology, Kansas Wesleyan University.
SIMKINS, CLEVELAND S., Harvard University.
SMITH, LOUISE, Instructor in Zoölogy, Smith College.
STACEY, HELEN R., Vassar College.
THOMPSON, MARTHA L., Teaching Fellow, University of California.
WALTERS, MARY J., 1633–29th St., N.W., Washington, D. C.
WILLIAMSON, JANET A., Instructor in Zoölogy, Mount Holyoke College.
WONDERGEM, HENRY E., University of Rochester.

PHYSIOLOGY.

CHACE, EUNICE E., Instructor, Smith College.
CROFTS, ELIZABETH E., Oberlin College.
GILSON, ARTHUR S., JR., Student, Harvard University.
GREENE, WALTER F., Assistant Instructor, Yale University.
HANNA, LEILA O., University of Toronto.
HEIZER, PAULINE, Student, Radcliffe College.
JOHNSON, GEORGE E., Professor of Biology, University of Porto Rico.
KLOPP, JOHN W., Swarthmore College.
KUYK, MARGARET P., Professor of Physiology and Hygiene, University of Richmond.
MALL, MARY L., Bryn Mawr College.
POLLAK, MARION H., 135 West 87th St., New York City.
THOMPSON, JAMES T., Wabash College.

WEED, ELEANOR H., Vassar College.
WOLLF, NATHANIEL S., 25 Portsmouth Terrace, Rochester, N.Y.
YEN, HUI C., Oberlin College.

BOTANY.

AMORY, WALTER, Student, Harvard University.
CHUTE, RICHARD, Student, Harvard University.
DODGE, CARROLL W., Assistant Professor of Botany, Brown University.
MADER, VIVIENNE C., Student, Connecticut College.
MASON, MARIAN, Student, Vassar College.
OSTERHOUT, ANNA M., Student, Vassar College.
ROGERS, LENETTE M., Student, Mount Holyoke College.
TODD, JESSIE E., 4539 Jackson Boulevard, Chicago, Ill.

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3. TABULAR VIEW OF ATTENDANCE

	1916	1917	1918	1919	1920
INVESTIGATORS—Total	129	129	93	134	136
Independent:					
Zoölogy	70	63	51	68	69
Physiology	23	23	16	24	22
Botany	7	8	5	7	7
Under Instruction:					
Zoölogy	25	24	16	21	29
Physiology	3	6	3	10	7
Botany	1	5	2	4	2
STUDENTS—Total	102	83	69	128	120
Zoölogy	50	46	41	55	56
Protozoölogy	—	—	—	15	15
Embryology	26	16	12	33	26
Physiology	14	13	10	17	15
Botany	12	8	6	8	8
TOTAL ATTENDANCE	231	212	162	262	256
INSTITUTIONS REPRESENTED—Total	73	77	72	88	86
By investigators	51	60	49	61	55
By students	45	36	38	62	57
SCHOOLS AND ACADEMIES REPRESENTED.					
By investigators	—	2	—	—	1
By students	3	5	—	4	7

4. CÖÖPERATING AND SUBSCRIBING INSTITUTIONS—1920

Barnard College
Bowdoin College
Bryn Mawr College
Butler College
Carnegie Institution of Washington
Carnegie Institution, Cold Spring Harbor
Columbia University
Connecticut College
Cornell University Medical College
Creighton University
Dartmouth College
Doane College
Eli Lilly & Co.
Goucher College
Harvard University
Harvard University Medical School
Hunter College
Johns Hopkins University
Knox College
Lake Forest College
Mount Holyoke College
Oberlin College
Princeton University
Radcliffe College
Rice Institute
Rockefeller Institute for Medical Research
Simmons College
Smith College
Sophie Newcomb College
Trinity College
University of Chicago
University of Cincinnati
University of Illinois
University of Kansas
University of Michigan
University of Missouri
University of Pennsylvania

University of Pennsylvania Medical School
University of the Philippines
University of Rochester
University of Toronto
University of Vermont
University of Wisconsin
Vassar College
Washington University
Wellesley College
Wesleyan University
Western Reserve University
Western State Normal School
Wheaton College
Wistar Institute of Anatomy and Biology
Yale University

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5. EVENING LECTURES, 1920

Friday, July 2,
Dr. G. H. Parker . . . . . "Activities of Renilla."
Tuesday, July 6,
Dr. C. R. Stockard . . . . . "Structure and Type as Influenced by Rate of Development and Growth."
Friday, July 9,
Dr. Jacques Loeb . . . . . "General Chemistry and Colloid Chemistry of Proteins."
Tuesday, July 13,
Dr. C. W. Metz . . . . . "Studies on the Relationships of Chromosomes in Different Species of Drosophila."
Friday, July 16,
Dr. R. M. Yerkes . . . . . "The Intelligence of Biologists."
Tuesday, July 20,
Dr. Charles Zeleny . . . . . "Some Factors Controlling Eye-Facet Number in Drosophila."
Friday, July 23,
Dr. Christine Ladd-Franklin . "Theories of Chromatic and Achromatic Sensations."

Tuesday, July 27,
DR. HENRY LAURENS....."The Investigation of the Stimulating Effect of Visible Radiation in an Equal-Energy Spectrum."

Friday, July 30,
DR. RAYMOND PEARL....."Some Problems in Human Biology."

Tuesday, Aug. 3,
DR. LEO LOEB....."Transplantation and Individuality."

Friday, Aug. 6,
DR. WARREN H. LEWIS....."The Reactions of Cells in Tissue Cultures."

Tuesday, Aug. 10,
MR. W. LYMAN UNDERWOOD ..."Adventures in the Land of Sunshine."

VI. MEMBERS OF THE CORPORATION.

1. LIFE MEMBERS.

ALLIS, MR. E. P., JR., Palais Carnoles, Menton, France.
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2. REGULAR MEMBERS, AUGUST, 1920.

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BEHRE, MISS ELINOR H., Louisiana State University, Baton Rouge, La.
BIGELOW, PROF. M. A., Teachers College, Columbia University, New York City.
BIGELOW, PROF. R. P., Mass. Institute of Technology, Cambridge, Mass.
BINFORD, PROF. RAYMOND, Guilford College, Guiford College, N. C.
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CARVER, PROF. GAIL L., West Lake, Ga.

CARY, DR. L. R., Princeton University, Princeton, N. J.

CASEY, COLONEL THOMAS L., Washington, D. C.

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JACOBS, PROF. MERKEL H., University of Pennsylvania, Philadelphia, Pa.

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JENNER, PROF. A. E., Simpson College, Indianola, Iowa.

JEWETT, PROF. J. R., Harvard University, Cambridge, Mass.

JONES, PROF. LYNDS, Oberlin College, Oberlin, Ohio.

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STUDIES ON THE PARASITIC WASP, HADROBRACON BREVICORNIS (WESMAEL).

I. Genetics of an Orange-eyed Mutation and the Production of Mosaic Males from Fertilized Eggs.

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Introduction.

In a previous paper (1918) I gave a brief account of the general biological relationships and the method of sex-determination in the parasitic wasp, *Hadrobracon brevicornis* (Wesmael). The experiments there reported were begun in the fall of 1916 and continued through the winter. Difficulties in rearing the host caterpillars in sufficient quantity induced me to abandon the work on the wasp and to concentrate on the host, the Mediterranean flour-moth, which was also being investigated genetically. When these technical difficulties were overcome, the work with *Hadrobracon* was renewed and has been continued since June, 1919. During the summer of 1919, the wasps were bred at the Marine Biological Laboratory, Woods Hole, Massachusetts; during the winter of 1919–20, at Franklin and Marshall College, Lancaster, Pennsylvania; and during the summer of 1920 at the Carnegie Station for Experimental Research, Cold Spring Harbor, Long Island. The work is being continued at St. Stephen's College, Annandale-on-Hudson, New York.

My grateful acknowledgments are due for the hospitality of the Woods Hole Laboratory and of the Carnegie Station at Cold Spring Harbor. I am also indebted for financial aid to the Carnegie Institution of Washington and to the American Association for the Advancement of Science from which I have received two grants for research. Mrs. Whiting has given me valuable assistance in the course of the work.

A type of reproduction in which virgin females produce only males while mated females may produce either males or females

has been shown to occur in several groups. Such "male-producing" species are called arrenotokous and it has been supposed that all males arise from unfertilized eggs, females from fertilized. This theory bears the name of Dzierzon (1845) who first applied it to the honey-bee. The males produced by mated females are assumed to develop from eggs into which spermatozoa have not penetrated. Cytological observations showing that males of several arrenotokous species are haploid, while females are diploid tend to corroborate the theory derived from breeding tests.

The only published experimental work on arrenotokous forms showing the method of inheritance of any character difference, other than that of sex, appears to be in crosses of different races of honey-bees. "Criss-cross" inheritance is the rule; the males resemble the mother, while the females inherit characters from both parents. Cross-bred females produce drones showing segregation in expected one to one ratio. From the similarity of these phenomena to sex-linkage, this method of inheritance may be called *sex-linkoid*.

Presentation of Data.

(*a*) *Black-eyed Stocks.*—The results in reference to sex-determination published in my previous paper (1918) showed that the stock of *Hadrobracon brevicornis* obtained in Philadelphia at that time was arrenotokous. The data may be briefly summarized as follows:

Sixty-one females set with males produced 683 males and 918 females.

Nine females set with males produced 197 males, no females.

Thirty-six virgin females produced 1,133 males, no females.

Impaternate sons were crossed back to their virgin mothers and in this way closely inbred daughters were obtained.

Another stock of *Hadrobracon* was secured in Philadelphia in December, 1917, and three virgin females were isolated, producing in all 244 males. One of these females was later mated to one of her sons and produced 9 males and 3 females.

Three males and one female were caught in Mifflintown, Pennsylvania, May, 1920. From eggs laid by this female there

were produced 4 males and 12 females. Seven virgin daughters produced 804 males, and one of these females when later crossed to a son produced 34 males and 5 females.

The Lancaster stock, upon which most of the work with *Hadrobracon* has been done, was derived from a single parasitized caterpillar found in my cultures of the Mediterranean flour-moth at Lancaster in June, 1919. It is highly probable that the caterpillar was stung by a single female which came in from some bakery or grocery store near-by, as I had no cultures of *Hadrobracon* at that time. Seven females were reared, showing that the mother had evidently mated. These females, isolated without males, produced only males which were crossed back to their virgin mothers in order to obtain females. This stock has been bred since that time and has shown considerable variation.

It will be necessary to give only summaries of the typical black-eyed Lancaster stock as the data is very extensive and results in reference to other somatic variations and sex-ratio will be published later.

Fifty-three females, isolated as virgin, produced 5,948 males and no females.

Forty females, set with males, produced 3,944 males, no females.

One hundred thirty-five females, set with males, produced 7,270 males and 4,791 females.

We may now give the entire summaries of the black-eyed stocks, including two different stocks from Philadelphia, one from Mifflintown, and one from Lancaster.

From one hundred and thirty-five virgin females there were 9,242 males.

From forty-nine females set with males there were 4,141 males.

From one hundred and ninety-nine mated females there were 8,000 males and 5,729 females.

I feel very certain that among all these wasps there were none of the orange-eyed variety described below. The difference between the typical black-eyed form and orange is so striking and the eyes of the wasp are so large that such a variation could not escape attention. Moreover the material bred was examined with some care as one of the main purposes of the work was to find genetic differences.

(*b*) *The Orange Mutation.*—On March 11, 1920, a female, in all respects typical, was isolated as a virgin. Her progeny consisted of 253 black-eyed males and 1 male with orange eyes. This mutant occurred in the first bottle in which the mother had been kept for a period of seven days. The count from this bottle on March twenty-seventh numbered 46 including the mutant. The cultures were at that time developing in the incubator at thirty degrees centigrade at which temperature the period from oviposition to eclosion is about ten days. The mutant may have emerged a few days before the count was made. In any case the egg from which he came was laid within the first seven days of the adult life of the mother which lived until April 1. The mutation may have occurred during the development of a single egg; at least it could not have taken place many cell generations before maturation.

The compound eyes of the mutant were rather light orange. They became slightly darker with age. He was kept alive until May tenth and was mated to various females. "Orange" eyes as they have appeared in later generations are not necessarily orange. They are found to vary from very light cream to deep red and from yellowish orange to pink. No trace of a black fleck such as occurs in the eye of *Drosophila* has been found. The peripheral ommatidia appear black, but this is due, as sections show, to black pigment in the underlying and adjacent integument. Black pigment is also entirely lacking from the ocelli, although here again it occurs in the adjacent integument. In the typical wasp the eyes, both compound and simple, are always jet black. Variations in orange are not considered in the present paper which is concerned only with the difference between black and orange.

(*c*) *Sex-linkoid Inheritance of Orange.*—The mutant was crossed successfully with six black females and offspring were reared as follows:

Culture No.	Black Males.	Black Females.
178	81	94
179	49	65
180	73	87
182	39	68
183	162	67
185	1	2
Total... 6	405	383

By expectation from sex-linkoid inheritance the daughters should carry orange, the sons should be without it. The dominance of black was complete. Four isolated daughters bred as follows:

Culture No.	Origin.	Black Males.	Orange Males.
194	178	94	129
198	178	90	91
199	180	16	25
202	179	68	81
Total...4		268	326

The excess of orange over the expected one to one ratio indicates that orange is not deficient in viability.

Eight daughters that had mated with their brothers bred as follows:

Culture No.	Origin.	Black Males.	Orange Males.	Black Females.
188	178	48	32	77
189	"	30	43	51
190	"	26	32	70
191	"	23	14	49
192	"	65	68	58
196	"	26	26	50
197	"	37	21	63
212	183	2	3	7
Total 8		257	239	425

The failure of orange to appear in the females is to be expected from sex-linkoid inheritance.

The mutant orange male was crossed successfully to three of his heterozygous daughters and produced offspring as follows:

Culture No.	Origin.	Black Males.	Orange Males.	Black Females.	Orange Females.
193	178	52	66	27	36
200	180	81	75	13	16
201	179	88	102	4	7
Total ..3		221	243	44	59

Here in accordance with expectation the orange-eyed females appeared for the first time. In eye color they resembled the

orange males and in later generations have shown apparently the same range of variability. The numerical deficiency of females as compared with their brothers is in this case probably due to the age of the mutant when mating occurred and a consequent scarcity of spermatozoa.

The mutant was set with four of his orange granddaughters, but only a single female was obtained. The record of offspring is as follows:

Culture No.	Origin.	Orange Males.	Orange Females.
209	193	211	0
211	193	120	0
312	201	136	1
313	201	88	0

The single orange female from mating 312 was crossed to one of her brothers and produced 35 orange males and 47 orange females. Twenty-five of these orange females, isolated as virgin, produced 2,549 orange males. By back-crossing some of these males to their virgin mothers, orange females were produced and a stock obtained which has since bred true.

Further crosses involving orange may now be summarized.

Twenty-nine black females from various homozygous black stocks crossed with various orange males, produced all black, 1,369 males and 665 females.

Two pairs of heterozygous females by black males produced 28 black males, 26 orange males, and 39 black females.

Twenty-six heterozygous females derived from various crosses of black by orange produced only males, 967 black and 996 orange.

Seven other heterozygous females crossed with orange males produced 170 black males, 151 orange males, 82 black females and 99 orange females.

Thirty virgin orange females derived from various sources produced 2,996 orange males, no females.

Twenty-eight orange females set with males produced 3,365 orange males, no females.

Forty-seven orange females, from various sources mated with orange males likewise from various sources, but not from the cross of orange female by black male, produced only orange, 2,333 males and 1,002 females.

The progeny from orange males derived from orange females crossed with black males are summarized below.

The inheritance is thus far seen to be quite in accordance with expectation.

The case must be mentioned of the occurrence of a single orange male in a cross (237) involving only type stock. There were produced 115 black males and 83 black females besides this orange male. This was possibly a second mutant as it is highly improbable that contamination of the culture could have taken place.

(*d*) *The Occurrence of Anomalous Males.*—The cross of black male by orange female remains to be considered. Black daughters and orange sons are to be expected. Thirty-three such crosses have been made and the results are summarized in Table 1. Eleven agree with expectation, giving 183 black females and 445 orange males. The other twenty-two, however, produced in addition to 816 black females and 889 orange males, *57 black males.*

It has been shown above that the sons of virgin orange females have always been orange. These anomalous blacks must then have derived their eye color from the sperm nucleus, and consequently must have developed from fertilized eggs.

Anomalous black males and some of their orange brothers were tested by mating to orange females. Table II. shows the results of these tests. Seven black males produced orange daughters only, showing that although their eyes were paternal in origin their gonads were from maternal nuclei. They are therefore mosaics. One of these males, No. 2, was mated successfully to five orange females and sired in all 118 orange daughters.

Five black males produced black daughters only and hence their gonads as well as their eyes were of paternal tissue. One of these, No. 8, was tested with two females.

Eighteen orange males sired orange daughters only. These males were therefore produced in regular manner from unfertilized eggs or, if sperm nuclei entered, they took no part in the formation of eyes or gonads.

One orange male, No. 17, produced 19 black daughters, thus

showing that although his eyes were orange his gonads were paternal in origin.

From the foregoing data it is to be noted that, while black females may be heterozygous and thus diploid for the orange locus, males produce one type of sperm only, which may carry either black or orange but not both.

TABLE I.

PROGENIES FROM BLACK MALES BY ORANGE FEMALES.

Culture No.	Black Males.	Orange Males.	Black Females.
205	4	65	41
207	6	67	61
214	1	28	34
219	3	85	67
281		11	14
282	1	35	42
289	3	23	21
340	1	8	58
342	2	39	45
343	6	49	47
344	2	86	77
381		161	38
384	1	62	64
387	1	13	11
388	1	30	34
391	4	42	13
393	3	38	42
394		36	21
395		20	22
396	1	17	15
397	3	42	34
398	2	31	16
399		4	1
400	1	37	22
401		16	8
402	2	34	17
403		13	16
404		26	34
405	4	36	32
407		2	2
408		4	2
409	5	22	23
554		152	25
Total 33	57	1334	999

When pairs of wasps are set together it often happens that the female will refuse to mate and will kick the male away, bending her abdomen down and forward. Her eggs then produce only males as expected. The same male, set with another female or with the same female at another time may succeed in siring

TABLE II.

TESTS OF ANOMALOUS MALES AND ORANGE BROTHERS.

Males.			Offspring.		
No.	Origin.	Character.	Orange Males.	Orange Females.	Black Females.
1	219	Orange	81	63	
2a	219	Black	167	28	
2b	"	"	30	24	
2c	"	"	66	24	
2d	"	"	75	35	
2e	"	"	10	7	
3	282	"	83	40	
4	342	Orange	112	58	
5	"	"	10	8	
6	"	"	65	58	
7	343	Black	24		3
8a	344	"	192		2
8b	"	"	58		19
9	"	Orange	4	2	
10	384	"	10	11	
11	"	"	6	14	
12	"	"	11	17	
13	"	"	19	26	
14	387	Black	44	41	
15	388	"	35		1
16	391	"	100	64	
17	"	Orange	67		19
18	"	"	37	14	
19	393	Black	45	1	
20	"	Orange	54	30	
21	"	"	23	34	
22	"	Black	104	65	
23	"	Orange	36	17	
24	"	"	90	48	
25	396	Black	94		1
26	397	Orange	81	73	
27	"	"	173	1	
28	"	Black	191		1
29	"	Orange	87	52	
30	"	"	3	6	
31	409	Black	21	3	
Totals.....	18	Orange males	902	532	—
	1	Orange male	67	—	19
	7	Black males	745	332	—
	5	Black males	594	—	27

daughters. Male broods, therefore, do not necessarily mean that the male is sterile. In the case of anomalous males, however, an apparently successful mating frequently results in no daughters or as Table II. shows, in very few, although the female may be highly fertile as indicated by the number of sons produced. Data in reference to this matter are not yet extensive enough for a thorough analysis, and it is therefore thought best to defer publication until later.

Discussion.

(*a*) *Sex-linkoid Inheritance in the Honey-bee.*—Johannes Dzierzon (1845) based his theory of the parthenogenetic origin of drones of the honey-bee, in part at least, upon crosses of various races. Clear evidence of sex-linkoid inheritance in the bee has been recently furnished by Newell (1914) who crossed a yellow Italian queen to a gray Carniolan drone. All the offspring were yellow. The reciprocal cross produced yellow females and gray males. Heterozygous females produced yellow and gray drones in equal numbers.

Many investigators have crossed Italian bees to the black French or German forms. Sex-linkoid inheritance appears to be the rule here also but there are numerous apparent exceptions.

Perez (1879) crossed yellow Italian queen to black French drone and examined three hundred drone offspring. Forty-nine showed markings interpreted as of paternal origin.

Cuénot (1909) crossed black female to yellow male and obtained females, all of which had yellow bands; three hundred black males; twelve males with small amount of yellow; and two males with broad yellow bands.

Inasmuch as drones intergrading between black and yellow occur it is natural to suppose that there is more than one factorial difference between the two races. It has been suggested that those males which were apparently more or less patroclinous might have arisen from eggs laid by hybrid workers, or that the queen might have been of mixed origin. It may be, however, that the intergrading drones were mosaics, comparable to the mosaic males of *Hadrobracon*.

(*b*) *Sex Determination and Parthenogenesis.*—In most animals there appears to be a sex-difference in chromatin content. This varies, from a theoretical minute portion of one chromosome to a clearly visible difference of one or more chromosomes. In the case of haploid parthenogenesis, the male has the haploid number, and reduction of the egg nucleus takes place in a normal manner. This occurs apparently in at least most of the Hymenoptera, in the white fly (Stoll, 1919; Schrader, 1920) and probably in several other forms. Diploid parthenogenesis occurs in many

animals. It may result in the production of either males or females, but in Hymenoptera it results in females only, the males being haploid, with the possible exception of the saw flies (Doncaster, 1907). Goldschmidt (1917) has given a convenient classification of types of parthenogenesis.

From the work already done on *Hadrobracon* it appears that parthenogenesis is strictly haploid and therefore arrenotokous. The females are certainly diploid and arise in all cases from fertilized eggs. But it does not therefore follow that all males come from unfertilized eggs, or that such males as arise from fertilized eggs are diploid.

The suggestion has been made that males in Hymenoptera might occur, having the number of chromosomes diploid, except for the sex-chromosome, which might occasionally pass out in the abortive division of the first spermatocyte. Fertilization by the resulting spermatozoön would result in diploid males. In *Hadrobracon* all males, thus far studied, even the anomalous males, appear to be haploid for the orange locus.

(*c*) *The Bearing of Mosaics on Problems of Fertilization.*—An interesting problem in the occurrence of anomalous, mosaic males centers in fertilization. In the physiological sense, fertilization means the stimulation necessary to initiate development. In forms which are normally parthenogenetic, this stimulation is unnecessary and the entrance of the spermatozoön into the egg can hardly be called physiological fertilization. The egg is already fertile before the appearance of the male cell. In the genetic sense, however, fertilization denotes the union of paternal with maternal germ plasm, or amphimixis. In this sense an egg producing an anomalous male is fertilized, for paternal germ plasm is brought into it, although this is not followed by fusion of nuclei, as is usually the case.

In order to explain sex-mosaics or gynandromorphs it has been suggested that a paternal nucleus might fuse with a maternal, the diploid product giving rise to the female parts of the embryo. Male parts are assumed to be derived from haploid nuclei of paternal, maternal or mixed origin. Polyspermy has been suggested by Morgan (1905) to explain the Eugster gynan-

dromorph bees, but Boveri (1915) contended that the male parts were of maternal color and held that a single sperm nucleus had fused with one of the products of parthenogenetic cleavage. Morgan's hypothesis apparently fits the von Engelhardt bees (1914) in which the male parts resembled the father. Cleavage of a single sperm nucleus, however, might be followed by subsequent fusion of one of the products with the female pronucleus and a result would be obtained similar to Morgan's hypothesis of polyspermy. It is also obvious that haploid nuclei might be derived from both parents and the resulting male parts would then be of mixed origin.

Doncaster (1914) has demonstrated the existence of binucleated eggs in *Abraxas;* and it has been suggested that if one of these contained the sex-chromosome and the other lacked it, their simultaneous fusion with two sperm nuclei would result in a gynandromorph.

Morgan and Bridges (1914) have shown that in *Drosophila* gynandromorphs and other mosaics result from dislocation of a sex-chromosome during cleavage or embryonic development. The male parts are here of course diploid for autosomal factors.

Mosaics due to somatic mutation have likewise been reported in several plants and animals.

It is to be noted that the mosaic males reported in the present paper result from the cross of orange female by black male. The reciprocal cross has failed to give any anomalous results. Whether the production of anomalous males is necessarily correlated with the fact that orange comes in from the mother, black from the father; or whether black females may be obtained which will give anomalous results when crossed to orange males, is uncertain. In the former case the orange factorial difference would itself be responsible for the production of anomalous males. In the latter case the production of irregularities would perhaps depend upon a factorial difference other than that of orange. The answers to this question and to others raised in the present paper may be given by investigations now in progress.

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CHROMOSOMES AND THE LIFE CYCLE OF HYDATINA SENTA.[1]

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A reëxamination of the chromosomes of this rotifer seemed desirable owing to the results of some of my early experiments (Shull, '12), in which it was shown that whether one of these rotifers is to be a male-producer or female-producer is irrevocably decided within a period several hours in duration occurring in the course of maturation of the parthenogenetic egg from which the individual develops. Influences acting upon the egg before and after that period were found to be without effect. This result indicated that some very brief event occurring in maturation decided the fate of the female arising from the egg, and it seemed possible that the event might be a change in the number of chromosomes, perhaps comparable to the chromosome change in the aphids and phylloxerans, in which the diminished number in the male is still greater than the haploid. Sharp distinction between male-producers and female-producers is known in the phylloxerans without any difference in the chromosome number (Morgan, '09); but in these insects the time at which the differentiating event occurs is unknown.

A difference in the number of chromosomes between male-producers and female-producers was not excluded by the results of previous studies of the cytology of *Hydatina*. Lenssen ('98) states the number of chromosomes to be 10 or 12 in the female-producing egg. In one passage it is plain that these numbers imply uncertainty as to the correct number. Perhaps uncertainty was intended to be implied by the other passages in which the expression "10 or 12" is used, but there is room in one case to suppose that Lenssen observed sometimes 10, sometimes 12,

[1] Contribution from the Zoölogical Laboratory of the University of Michigan. For aid in the laborious task of preparing the specimens from which this study was made the author is indebted to the trustees of the Bache fund.

in different eggs. If such differences existed, they might represent the two types of female. The possibility that Lenssen believed the number of chromosomes to be different in different individuals is heightened by his statement that the reduced number in the egg of the male-producer is "probably five." This would suggest 10 as the diploid number in the male-producer, though maturation phenomena might reduce the haploid number to less than half the diploid.

Whitney's ('09) studies threw no light on Lenssen's statements, for he was unable to count the chromosomes with accuracy. Using American specimens, he arrived at a diploid number between 20 and 30, the highest number actually counted being 25. There was nothing in the male egg or fertilized egg to render the count more definite, for the number discovered in the male egg ranged from 10 to 14, and in the fertilized egg, during maturation, 14 was the largest number seen.

In view of the uncertainty of these determinations, and of the possibility that the male-producing and female-producing females might differ in their chromosome number, I undertook a re-examination of this difficult material. Notwithstanding the difficulties, I have a fair degree of confidence in the conclusion reached.

Preparation of Material.

Although several fixing agents were used, the specimens that were good enough to study were all fixed in Bouin's fluid. Dehydration was accomplished by the drop method. When the objects had reached 70 per cent. alcohol, they were carefully wrapped in bits of stratum corneum of frog skin, which had shortly before been put into 70 per cent. alcohol, in order to make the objects large enough to imbed easily. The frog skin was held in compact form by fragments of cover glass until the objects were in 96 per cent. alcohol, by which time the skin had hardened so that it would not unroll. Six to eight rotifers were as a rule wrapped in each roll. Sections were all cut 5 μ in thickness. All were stained in iron-hematoxylin. They were also lightly stained with eosin, but not for the purpose of this study. Unfortunately the chromosomes show a strong tendency

to collect in masses, so that the number of specimens clear enough to furnish counts was not large.

General Course of Maturation.

Inasmuch as I was primarily interested in the number of chromosomes, in each of the kinds of females, I have made no attempt to render a complete account of maturation. Such facts as have been revealed, even though incidental to the main object, are here recorded. Only that part of the maturation which occurs in the oviduct of the female has been studied. The completion of the process after the egg is laid has not been followed.

About the time when the oöcyte has reached its maximum size and is fairly fixed in form (ellipsoidal), not yielding to the movements of the body of the female, the nucleus rapidly increases in volume. An aster appears in the cytoplasm near it, being readily visible by the practical absence of yolk spherules, although radiations are very indistinct. So plain is the aster that it was invariably used as a guide-post in locating maturation spindles. The spindle is formed within the nucleus. Upon it the chromosomes appear as long slender threads tapering toward both ends (Fig. 1). As the spindle develops the nuclear membrane disappears, so that the spindle is out in the cytoplasm: but there is always a definite space in the cytoplasm in which the spindle is located so that there is no confusion of chromosomes and yolk spherules. With very few exceptions, the spindle, which is near the periphery of the cell, is turned toward the intestine. Exceptions to this rule are more common in male-producers than in female-producers.

In the female-producing egg the chromosomes arrange themselves on the equator. In this condition the cell appears to remain until the egg is laid, for out of a large number of specimens not one was found that had proceeded beyond that stage. Lenssen ('98), indeed, concluded that the division was never completed; but Whitney ('09) observed the single polar body at the periphery of the segmenting egg.

In the male-producing egg several specimens indicate that the chromosomes meet in pairs on the equator of the spindle. The

pairs separate into their components, each group proceeding to the end of the spindle. In this late anaphase the cell appears to remain until the egg is laid, for out of many specimens none was found in later stages.

Number of Chromosomes.

The tendency of the chromosomes to adhere to one another in masses has rendered the determination of their number difficult. Fortunately in my material a number of specimens appear to agree in the number, and this is the largest number found. In such specimens the chromosomes are of approximately uniform size, while in cells showing smaller numbers some chromatin masses are nearly always distinctly larger than others, indicating that the larger bodies are probably compound. From a study of this material I conclude that the diploid number of chromosomes is 12. In female-producing parthenogenetic eggs, the best stage for counting the chromosomes is just before or during the formation of the equatorial plate, because the chromosomes are then well-defined, and are not so crowded as later in the equatorial plate. Such a stage is represented in Fig. 2.

The chromosomes of the male-producing egg can be counted fairly well at several stages. As in the female-producing egg, one favorable stage is just before the formation of the equatorial plate. In the equatorial plate the chromosomes can also be counted, in these eggs, because the chromosomes unite in pairs, hence there is a smaller number of discrete objects, and they are not so crowded. Figure 3 shows distinctly six pairs. In this figure the equatorial plate is viewed obliquely, and the pairs are not at the same level, a fact not shown in the drawing. In Fig. 4 there are six bodies, of which three show signs of bivalence. The others may be bivalent, but appear single because viewed from the end of the spindle. In late anaphases of the male-producing egg the chromosomes are always crowded. Five chromosomes can usually be recognized, but some specimens show six. From the existence of six pairs on the equatorial plate, I conclude that the number must be six even where only five can be recognized. The late anaphases which are favorable

FIG. 1. Maturation spindle of male-producing egg being formed within nucleus. A distinct nuclear membrane is still present. Only part of the spindle is in this section.

FIG. 2. Equatorial plate of maturation spindle of female-producing egg.

FIG. 3. Metaphase of first maturation spindle of egg of a male-producer. The spindle is viewed obliquely from the side, and the chromosomes are not all at the same depth in the specimen.

FIG. 4. Metaphase of the first maturation spindle in a male-producing egg. The view is nearly polar. Three of the chromatic bodies, set obliquely, give indications of being bivalent; the rest appear single.

FIG. 5. Portion of first maturation spindle, in late anaphase, of male-producing egg. The spindle is cut obliquely, and the outer end is here shown.

FIG. 6. Inner group of chromosomes, six in number, in late anaphase of first maturation division of male-producing egg.

enough to count include one or more groups at both outer (Fig. 5) and inner (Fig. 6) ends of the spindle, and the number is six in either case.

Discussion.

From the best evidence I have been able to obtain, the number of chromosomes in *Hydatina senta* must be placed at 12. The number appears to be the same in male-producers and female-producers. This conclusion is less illuminating in some respects than might have been expected, but simplifies the probable chromosome behavior in certain parts of the cycle. The very sharply defined distinction between male-producers and female-producers, and the irrevocable determination of the nature of the egg at the time of maturation, would be regarded as "explained" if it could be shown that they rested on chromosome differences. If there are such differences, they are not differences of number. Whatever change occurs at maturation, to distinguish eggs that yield male-producers from those that yield female-producers, must, however, be quite as definite an event as the loss of a chromosome to the polar body.

With regard to the male phase of the life cycle, one may surmise the following consequences of the uniformity of chromosome number. The male probably develops with the haploid number of chromosomes, and in the maturation of his spermatozoa the reduction division is either abortive or suppressed. Or the male may at some stage double the number of chromosomes and maturation include a numerical reduction. In either case, the spermatozoa should contain six chromosomes. The sexual egg (identical with the male-producing egg described in this paper) presumably also has six chromosomes. At fertilization the number is restored to 12.

The status of the females hatching from fertilized eggs, which may be called the stem mothers, is a peculiar one. These stem mothers have been shown by hundreds of determinations to be always female-producers (Shull, '12). Whether, in the absence of differences in chromosome number, the feature which distinguishes a female-producer derived from a parthenogenetic egg from a male-producer is also the feature which makes a stem mother a female-producer can only be conjectured at present.

I am not prepared to advocate any view as to the method by which, in the absence of visible chromosome differences, a female-producer is distinguished from a male-producer. It has been suggested to me that there may be a difference in the chromatin, perhaps a quantitative difference, which does not involve the number of chromosomes. This possibility may be investigated in other ways. If there is a single fundamental distinction between the two kinds of females, any attempt to discover it must take account of the fact that the distinguishing feature of the female-producing parthenogenetic egg must also be an attribute of the fertilized egg.

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